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Generation of Ballistic Meteorological Messages - Surface to Surface (METB3s) from Computer Meteorological Messages (METCMs)

by James Cogan and David Sauter

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Computational and Information Sciences Directorate, ARL

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14. ABSTRACT

The armed forces of many North Atlantic Treaty Organization (NATO) members and other nations have used ballistic meteorological (MET) messages for surface to surface trajectories (METB3s) for many decades. It was developed before users had ready access to computers on the battlefield and is normally applied in a manual mode. The later computer MET message (METCM) came into use, as the name implies, after the advent of battlefield computers and continues to be widely used. Some newer artillery MET systems no longer generate METB3s since modern fire control systems use METCMs, and in some NATO nations, the more recent gridded MET message (METGM). Nevertheless, for certain applications and as a backup, there is a requirement to be able to produce a METB3 from a METCM generated locally or transmitted from another artillery MET system. This report briefly discusses a program that converts a METCM into a METB3, which can be applied to specific systems with appropriate modifications, and outlines a modified version for a handheld device. The program applies methods found in available field manuals and NATO publications. Some of the algorithms embodied in the program were extracted from a similar spreadsheet-based method developed at the Armament Research, Development and Engineering Center (ARDEC).

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1. Introduction

The armed forces of many North Atlantic Treaty Organization (NATO) members and other nations have used ballistic meteorological (MET) message for surface to surface trajectories (METB3s) for many decades. It was developed before users had ready access to computers on the battlefield and is normally applied in a manual mode. The later computer MET message (METCM) came into use, as the name implies, after the advent of battlefield computers and continues to be widely used. Some newer artillery MET systems no longer generate METB3s since modern fire control systems use METCMs and, in some NATO nations, the more recent gridded MET message (METGM). Nevertheless for certain applications and as a backup, there is a requirement to be able to produce a METB3 from a METCM generated locally or transmitted from another artillery MET system.

This report briefly discusses a program that converts a METCM into a METB3, which can be applied to specific systems with appropriate modifications, and outlines a modified version for a handheld device. The program applies methods found in available field manuals and related NATO publications. Some of the algorithms embodied in the program were extracted from a similar spreadsheet-based method developed at the Armaments Research, Development, and Engineering Center (ARDEC). In addition, the report contains some samples of input and respective output messages.

2. Method

The METCM normally contains 32 data lines (zone or line 0 through 31), one for each message zone or layer. Except for the surface each line of MET data has mean values for the respective zones. The surface essentially repeats the values measured or generated by a numerical weather prediction (NWP) model for the surface. When a METCM is transmitted manually or when it is derived from radiosonde data, it may have fewer than 32 lines. The METB3 has 19 lines of data, but unlike the METCM each line above the surface (line or zone 0) contains a weighted mean of the mean values for that zone and all zones below not including zone 0. For example, the temperature for zone 5 is a weighted mean of the mean zone values for zones 1 through 5. The weighted mean value at line or zone 1 (0–200 m) is the zone value itself (weight of 1.00). Details on the METCM and METB3 may be found in Army field manuals (e.g., FM 3-09.15 (FM6-15)/MCWP 3-16.5, FM 6-16, and FM 6-40/MCWP 3-1.6.19) and NATO standardization agreements (e.g., STANAG 4061 and STANAG 4082) including information on message formats, variables, and required header data. The METGM is outside the scope of this report, but a description may be found in STANAG 6022.

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The METCM and METB3 differ in some variables and formats. The METCM has wind speed in knots, wind direction in tens of mils, virtual temperature in tenths of K, and pressure in mb. The METB3 has weighted values as noted above for wind speed in knots, wind direction in hundreds of mils, sensible temperature in percent of the standard atmosphere value, and density in percent of standard. For temperature and density, round the percent of standard to the nearest tenth of a percent and multiply by 10, and for numbers ≥1000 subtract 1000 (e.g., 98.3 becomes 983 and 100.9 becomes 009). Table 1 shows a sample METCM for the first three lines with the relevant units, and table 2 has a sample for a METB3. Both samples were based on messages from Yuma Proving Ground (YPG) that were derived from a radiosonde sounding. More complete examples may be found in appendix A. Different versions of the input routine of the program briefly described in this report can read other formats such as the METCM produced by the Computer, Meteorological Data – Profiler (CMD-P), also found in appendix A.

Table 1. Variables and formats for the first 3 lines/zones of a sample METCM based on radiosonde data from YPG.

Zone height (m at top)	Line Number	Wind Direction (10s of mils)	Wind Speed (knots)	Temp (virtual) (0.1 K)	Pressure (mb)
Surface	00	533	005	2788	0989
200	01	566	011	2817	0977
500	02	014	009	2815	0948

Table 2. Variables and formats for the first 3 lines/zones of a sample METB3 based on radiosonde data from YPG. See text for format of percent of standard values.

Zone height (m at top)	Line Number	Wind Direction (100s of mils)	Wind Speed (knots)	Temperature (% std)	Density (% std)
Surface	00	53	05	968	009
200	01	57	11	980	996
500	02	63	09	983	992

Part of the primary method used to produce METB3s employed variations of some of the algorithms found in the spreadsheet method from ARDEC (Ray, 2013). It used the same type of calculation of METB3 zone values prior to weighting and an algorithm for extrapolating METCM levels above the highest line where the input has less than the full 32 METCM zones. Both methods also compute and weight the horizontal wind components and then convert them to wind speed and direction. As noted above, the standard METB3 message contains sensible temperature, but the METCM has virtual temperature. Normally the difference is small above the lowest zones and usually can be ignored for trajectory calculations. The method of this report uses the virtual temperatures of the METCM for the METB3. Also, it's more accurate to use virtual temperature to calculate density than sensible temperature, especially where they differ by more than a very small amount.

The program's data ingest routine reads a METCM starting at the surface or zone 0. If the METCM ends before the highest zone (line 31), the user has the option of having the ingest routine extrapolate from the last input data line through line 31. Following the spreadsheet's method, the extrapolation sets the wind speed and direction the same as at the METCM's uppermost zone. The percent of standard of temperature at the highest input zone is multiplied by the standard temperature values for the extrapolated zones. The same procedure gives the extrapolated pressures, that is, the percent of standard at the highest input zone is multiplied by the standard pressures.

The following process calculates the un-weighted zone values for the METB3 from the input METCM. For the data lines above the surface, the METCM zone values are taken as the values at the midpoints. For the surface and where the zone midpoints of both messages are the same (e.g., for zone 2, midpoint at 350 m), the values from the METCM are copied into the METB3. For those zone midpoints that differ from one another, the program takes the average of the values for the METCM zone midpoints immediately above and below the midpoint of the relevant METB3 zone. Wind speeds and directions from the METCM zones are converted into their respective horizontal components (u, v) before being converted into METB3 zone values. Figure 1 illustrates the relation between the message zones and the two ways of generating the METB3 midpoint values.
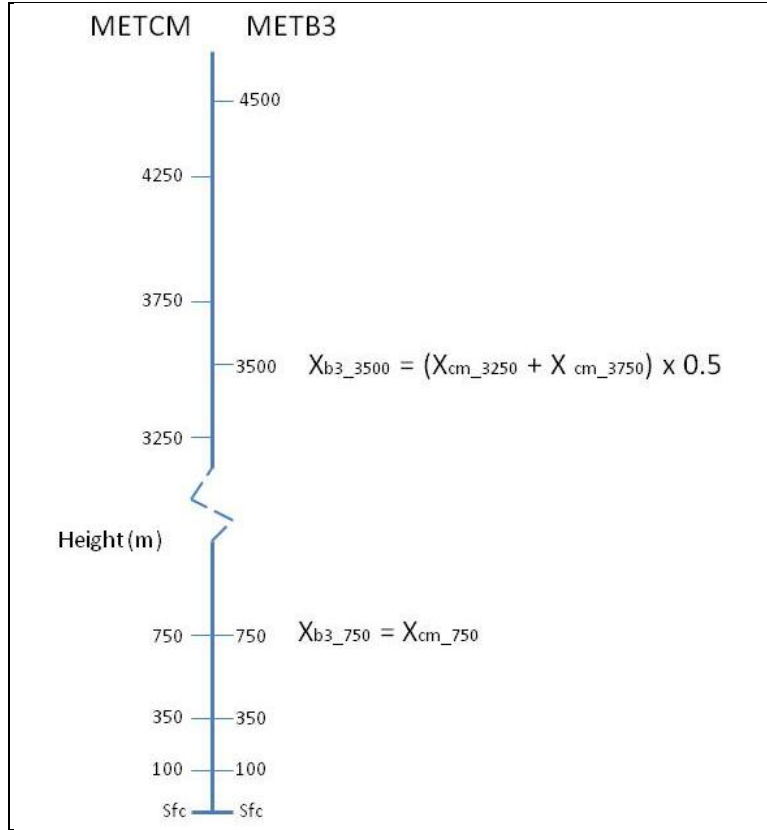
Figure 1. Illustration of the METCM and METB3 zone midpoint heights
and the method of obtaining METB3 zone values from METCM
zone values. X represents any variable and the subscripts (b3 for
METB3 and cm for METCM) indicate the message type and midpoint.
All heights are m above ground level (AGL).

An alternate method to the one described herein uses a process for computing METB3s similar
to that employed for other types of data such as from radiosondes (Cogan and Jameson, 2004) or
climatological tables (Cogan and Haines, 2013). This second method treats the METCM as it
would any appropriate vertical profile, where above the surface the values at each line of the
METCM are considered as data at the height of the midpoint of the zone. This method is nearly
the same as the primary one except they differ with respect to obtaining the midpoint values for
the individual METB3 zones prior to weighting.

Since the METCM does not have density it is computed from the virtual temperature and
pressure for the heights of the zone midpoints. The ideal gas law equation modified for moisture
via the use of virtual temperature is used to compute density (ρ):

$$\rho = P/RT_v \qquad (1)$$

where P is pressure (mb), T_v is virtual temperature (K), and R is the gas constant for dry air.
Density is in units of g/m^3.

Using the form of the equation outlined in the FMs as modified by ARDEC, we use the value of the inverse of 1/R to obtain

$$\rho = 348.36764 \ P/T_v \tag{2}$$

The weighting procedure is the same for both the primary and alternate methods. Weighting tables were developed some years ago and may be found in FM 6-16 and STANAG 4061. Appendix B reproduces the weighting tables as extracted from STANAG 4061. The concept is not difficult, though the programming of the process is somewhat complicated. Here we reproduce a part of the temperature (T) weighting table as table 3. Note that since METCM input is T_v, for the METB3 computations and output $T = T_v$.

Table 3. Part of the table of temperature weighting factors for computing METB3 weighted zone values. Table B-1 has the complete set of weighting factors along with the supplement shown in table B-2.

Line	Zone				
	1	2	3	4	5
1	1.00				
2	0.27	0.73			
3	0.13	0.20	0.67		
4	0.08	0.12	0.25	0.55	
5	0.05	0.10	0.20	0.21	0.44

For zone 0 (surface), there is no weighting and the METB3 uses the METCM values as noted above directly or as input for calculation of, for example, temperature and density as percent of standard. Line 1 has a weight of 1.00 and therefore is not modified except for the conversion to percent standard, etc. Using the temperature weighting factors of table 3 to obtain the value for line 2 the temperature at zone 1 is multiplied by the zone 1 weighting factor for line 2 (0.27), which is added to the temperature at zone 2 multiplied by its weighting factor for line 2 (0.73). For example, if $T_{zone1} = 290K$ and $T_{zone2} = 288K$, then $T_{line2} = 290*0.27 + 288*0.73 = 288.54K$. This result is then converted to % standard (% relative to 285.9K), which comes to 100.92%. For this example, the line 2 value would appear as 009 using the format described above. A similar procedure is followed for density, which also is expressed as a percent of standard.

For wind speed and direction, the procedure is somewhat different. For the surface (line 0), the wind components are the same as in the METCM. For lines 1 and above, up through METB3 line 18 (16–18 km AGL), the wind components are computed as above from the METCM's wind components. The components are weighted using the table for wind (appendix B). The weighted values of u and v are then converted into wind speed (knots) and direction (hundreds of mils). The procedure does not compare wind speed and direction with a standard set of values.

The output from this program is in a generalized format that has the variables and the structure of the METB3, but not the exact same format and header information as in the FMs. As suggested in appendix A, different users have somewhat different forms of the METB3 (e.g., Yuma

Proving Ground vs. FM 3-09.15 (FM6-15)/MCWP 3-16.5) as well as the formats of the input METCMs (Yuma vs. CMD-P vs. MMS-P, etc.). Modifications to the input and output routines can be made to accommodate different input and output formats, but the computation routines would not change. The program also may be revised so that it can run on a variety of processors including handheld or mobile computers.

3. Mobile Device Application

Earlier, the U.S. Army Research Laboratory (ARL) developed a capability to produce METCMs and METB3s directly from a surface MET observation and upper air wind vectors computed from the visual tracking and recording of pilot balloon (PIBAL) azimuth and elevation data measured at specific times after release. It consisted of an application that would run on a Windows Mobile based personal digital assistant (PDA) and also added the capability to compute a METB3 from the surface and PIBAL data. This application as described in Jameson and Sauter (2007) was tested, accepted, and fielded. A further capability was requested to convert a METCM that was already resident on the PDA or received from another system to a METB3 on the PDA. Consequently, the conversion software discussed in this report was re-hosted onto the PDA.

The requested METCM conversion utility also involved the receipt and transmission of MET messages to/from an Advanced Field Artillery Tactical Data System (AFATDS) via tactical radios. Thus, ARL teamed with ARDEC to develop the combined enhanced capability. ARDEC has extensive experience in the use of tactical communications to transmit and receive artillery-based information from the ruggedized PDA. Due to the concurrent development of the conversion and communications functionalities, it was decided to develop a version of the conversion routine as a dynamic link library (dll) for the PDA. This dll also would incorporate the existing PDA based capabilities and then be transitioned to ARDEC for integration with their current software package. As of the date of this report, an initial dll had transitioned to ARDEC, and was tested and integrated with their software. A formal testing and evaluation by the Marine Corps was slated for fall 2013. The dll is written in C++ and was developed using the Visual Studio 2008 Integrated Development Environment (IDE). The advantage of a dll implementation is that the library functions can be readily invoked via applications on other systems as well.

4. Summary of Results

The output from the program was tested against the ARDEC spreadsheet as well as output from YPG. Not surprisingly, the output using extrapolation matches that from the spreadsheet since both use the same basic algorithms for computing individual METB3 line values and weighted line values, as well as the same extrapolation algorithm. The only exception was the % density for lines ≥13 (midpoint at 11000 m). The ballistic standard for that line in the FM is slightly larger than that in the spreadsheet. When that one number was changed, the output METB3 from the two systems had the same values for all variables. Here we used the value found in the FM.

The METB3 output from YPG radiosonde data is slightly different. If the METB3 is computed directly from the radiosonde data, one would expect it to be somewhat different than if derived from the accompanying METCM. Unfortunately, the exact method of computing METB3s at YPG is not known since the software is proprietary and apparently no documentation is currently available. Appendix A contains a sample of METCM input and two resultant METB3s where one did not use extrapolation and other did. An additional example shows a METCM for YPG computed by a CMD-P and the consequent METB3. No extrapolation was needed since the METCM had all 32 zones.

The PDA dll implementation results were tested against the standalone version results for a number of cases, including a range of METCM lines from only line 0 to the maximum 32. The overwhelming majority of all of the output parameters matched exactly while a limited number differed by a value of ±1 in the least significant digit. This is deemed to be the result of rounding errors between the different processors on the standalone and PDA implementations and is not a concern.

5. Conclusion

This report briefly describes a computer program for producing a ballistic MET message for surface to surface fires (METB3) using a METCM for input. Though at first developed independently, it later incorporated certain algorithms expressed in a spreadsheet developed at the Firing Tables and Ballistics Division in ARDEC. The program was developed for eventual use on a handheld or mobile device, where a CMD-P or similar MET system would not be available. Nevertheless, it can be applied to any system where a METB3 is not directly computed as part of the primary software package. The only required modifications to the program as it currently exists would be in the input and output routines plus revisions to enable it to run with different operating systems and devices. A variant of the program already can read METCMs from a CMD-P, so in some cases little or no change to the input section would be needed. The net result is software to compute a METB3 from a METCM that can be applied with minimal modification to many systems that can generate or receive a METCM.

6.   References

Cogan, J.; Haines, P. *METCM-based Messages from Climatological Data*; ARL-TN-0528; U.S. Army Research Laboratory: Adelphi, MD, 2013.

Cogan, J.; Jameson, T. *Meteorological Message and Test Analysis Software for an Army Meteorological System*; ARL-TR-3249; U.S. Army Research Laboratory: Adelphi, MD, 2004.

FM 3-09.15 (FM6-15)/MCWP 3-16.5, Department of the Army, *Tactics, Techniques, and Procedures for Field Artillery Meteorology*, 2007, Washington, DC, 270 pp.

FM 6-16, Department of the Army, *Tables for Artillery Meteorology (Electronic) Ballistic Type 3 and Computer Messages*, 1979, Washington, DC, 142 pp.

FM 6-40/MCWP 3-1.6.19, Department of the Army and United States Marine Corps, *Tactics, Techniques, and Procedures for Field Artillery Manual Cannon Gunnery*, 1999, Washington, DC, 757 pp.

Jameson, T; Sauter, D. *Addendum to a PDA-based Backup System for Generating Marine Corps Artillery Meteorological Messages*; ARL-TN-279; U.S. Army Research Laboratory: Adelphi, MD, 2007, 14 pp.

Ray, C. Private communication, 2013.

STANAG 4082 (Edition 2), North Atlantic Treaty Organization - Military Agency for Standardization, *Adoption of a Standard Artillery Computer Meteorological Message*, 2000, Brussels, Belgium, 15 pp.

STANAG 4061 (Edition 4), North Atlantic Treaty Organization - Military Agency for Standardization, *Adoption of a Standard Ballistic Meteorological Message*, 2000, Brussels, Belgium, 28 pp.

STANAG 6022 (Edition 2), North Atlantic Treaty Organization – NATO Standardization Agency, *Adoption of a Standard Gridded Data Meteorological Message*, 2010, Brussels, Belgium, 36 pp.

Appendix A. Sample METCM Input from YPG and CMD-P and METB3 Output

Tables A-1 through A-5 include a sample of METCM type input from YPG and a METCM from a CMD-P along with output METB3 type data from the program. One of the YPG cases used extrapolation of the input METCM, the other did not. No extrapolation is needed for CMD-P METCMs since to date they have always had all 32 zones.

Table A-1. Input METCM produced from a radiosonde sounding from YPG dated 0800 MST on 11 FEB 2013. The GMT time (1430) indicates the approximate launch time of the radiosonde.

```
Computer Met Message For Flight: 13021108 Date: 02-11-13 Time: 0800 MST
   ID     Octant  Location  Date  Time  Duration Station HGT MSL Pressure
                                  (GMT)  (Hours)    (10's M)      (MBS)
   METCM     1    329 140    11    145      2        023           989
   ------------------------------------------------------------------------
        Zone      Line     Wind      Wind      Temp       Pressure
        Height    Number   Dir       Spd
        (Meters)           10s/mils  Kts      (1/10 K)   (Millibars)
   =========================================================================
           SFC     00       533      005       2788        0989
           200     01       566      011       2817        0977
           500     02       014      009       2815        0948
          1000     03       630      006       2785        0903
          1500     04       593      005       2747        0849
          2000     05       559      007       2702        0797
          2500     06       599      005       2658        0748
          3000     07       612      003       2614        0701
          3500     08       477      008       2576        0656
          4000     09       487      017       2539        0614
          4500     10       502      022       2499        0574
          5000     11       507      028       2459        0535
          6000     12       468      049       2431        0482
          7000     13       436      062       2371        0418
          8000     14       445      058       2331        0362
          9000     15       467      061       2316        0312
         10000     16       451      060       2297        0269
         11000     17       473      069       2267        0232
         12000     18       464      075       2256        0199
         13000     19       445      080       2234        0171
```

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Table A-2. Output METB3 derived from the YPG METCM of table A-1. The exact format of the METB3 may be different for other systems, but the variables and units are the same. No extrapolation was performed.

```
METB3 output

Date: 02-11-13
Time: 0800
Latitude:  32.90000
Longitude: 140.00000
Elevation:   23.00
```

Height (m)	Line	Wind Direction (100s of mils)	Wind Speed (kts)	Temperature (pcnt std)	Density (pcnt std)
0	0	53	05	967	009
200	1	57	11	980	996
500	2	63	09	983	993
1000	3	63	07	983	992
1500	4	61	06	982	992
2000	5	58	06	980	993
3000	6	60	05	974	995
4000	7	51	08	971	997
5000	8	51	15	966	998
6000	9	48	25	964	997
8000	10	45	40	964	993
10000	11	46	42	964	982
12000	12	46	48	964	975

Table A-3. Output METB3 derived from the YPG METCM of table A-1 where the message was extrapolated to the maximum METCM zone. The exact format of the METB3 may be different for other systems, but the variables and units are the same.

```
METB3 output

Date: 02-11-13
Time: 0800
Latitude:  32.90000
Longitude: 140.00000
Elevation:   23.00
 Height   Line    Wind Direction   Wind Speed   Temperature   Density
  (m)            (100s of mils)     (kts)      (pcnt std)   (pcnt std)


      0      0          53            05           967          009
    200      1          57            11           980          996
    500      2          63            09           983          993
   1000      3          63            07           983          992
   1500      4          61            06           982          992
   2000      5          58            06           980          993
   3000      6          60            05           974          995
   4000      7          51            08           971          997
   5000      8          51            15           966          998
   6000      9          48            25           964          997
   8000     10          45            40           964          993
  10000     11          46            42           964          982
  12000     12          46            48           964          975
  14000     13          45            52           964          975
  16000     14          45            54           964          977
  18000     15          45            53           964          978
```

Table A-4. Input METCM from a CMD-P obtained at YPG dated 6 FEB 2013 at 2130 GMT.

.

```
                            UNCLASSIFIED
To: AFATDS
+-----MET CM---------------------------------------------------------+
| Location: 7 66669 36 40617 0240 11                                 |
| Latitude (deg): 32.871264                                          |
| Longitude (deg): -114.149975                                       |
| Day: 06                                                            |
| Time: 21.5                                                         |
| Duration (hours): 0                                                |
| Station Height (10's m): 024                                       |
| MDP Pressure (mb): 0986                                            |
+---------+---------------+-----------+-------------+-----------+
```

Line Number	Wind Direction (10s mils)	Wind Speed (knots)	Air Temp (K)	Pressure (mb)
00	505	007	292.3	0986
01	507	008	291.6	0975
02	511	009	289.4	0946
03	519	008	286.0	0902
04	513	006	282.6	0850
05	540	006	279.2	0800
06	546	009	276.4	0752
07	534	014	273.7	0707
08	520	018	270.6	0664
09	515	022	267.1	0623
10	518	024	263.5	0584
11	519	027	260.0	0547
12	508	031	254.3	0495
13	497	036	246.0	0432
14	494	042	237.7	0375
15	487	050	231.0	0324
16	485	060	226.8	0279
17	483	068	225.0	0240

```
                            UNCLASSIFIED
                            UNCLASSIFIED
+---------+---------------+-----------+-------------+-----------+
```

18	480	073	223.8	0206
19	473	074	221.9	0177
20	465	072	218.8	0151
21	459	068	214.4	0129
22	455	063	210.3	0110
23	452	056	207.0	0093
24	450	047	204.5	0079
25	444	037	203.8	0067
26	430	027	206.8	0057
27	420	015	208.1	0044
28	475	008	207.1	0032
29	478	015	210.6	0023
30	473	027	217.9	0017
31	471	039	225.5	0012

Table A-5. Output METB3 derived from the METCM of A-4.

```
METB3 output

Date: 06
Time: 21.5
Latitude:  32.87126
Longitude: -114.14998
Elevation:   24.00
 Height   Line    Wind Direction  Wind Speed  Temperature   Density
   (m)            (100s of mils)    (kts)     (pcnt std)   (pcnt std)


       0      0          50           07          014          959
     200      1          51           08          014          960
     500      2          51           09          013          961
    1000      3          52           08          011          963
    1500      4          51           07          010          964
    2000      5          53           07          010          965
    3000      6          53           10          011          965
    4000      7          52           15          012          965
    5000      8          52           18          011          966
    6000      9          51           22          010          967
    8000     10          50           30          010          972
   10000     11          49           36          010          974
   12000     12          49           43          010          969
   14000     13          48           46          010          971
   16000     14          48           46          010          974
   18000     15          48           44          010          976
```

Appendix B. Weighting Tables from STANAG 4061

Tables B-1 through B-4 show the weighting tables for temperature, density, and wind as published in FM 6-16. The table numbers on the charts are those used in FM 6-16. Also included are the definition of standard atmosphere and the atmospheric structure of various meteorological messages from FM 3-09.15 (FM6-15)/MCWP 3-16.5 (table B-5). The standard atmosphere definition is that of the International Civil Aviation Organization (ICAO).

Table B-1. Weighting factors for temperature. See text for method of use. This table has zero values for weighting factors above line 9.

Table 2-7. Temperature Weighting Factors (Type 3 Message) (Surface-to-Surface Trajectories)

Line No.	Zone No.									
	1	2	3	4	5	6	7	8	9	10-15
1	1.00									
2	0.27	.73								
3	0.13	.20	.67							
4	0.08	.12	.25	.55						
5	0.05	.10	.20	.21	.44					
6	0.04	.04	.09	.11	.13	.59				
7	0.02	.04	.07	.09	.11	.26	.41			
8	0.01	.03	.05	.04	.10	.19	.23	.35		
9 to 15	0.01	.01	.02	.03	.03	.09	.13	.24	.44	0.00

Table B-2. Supplemental temperature weighting factors for lines 10–15 from STANAG (4061). They were not used in the current program or in the ARDEC spreadsheet. However, they could be added using a modification to the one temperature weighting parameter file (as verified with test cases) without modifying the program.

Line No. - Ligne No.	STANDARD HEIGHT ABOVE MDP / HAUTEUR AU-DESSUS DU MDP (M)	ZONE NO. - ZONE NO.														
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
		0 to 200	200 to 500	500 to 1000	1000 to 1500	1500 to 2000	2000 to 3000	3000 to 4000	4000 to 5000	5000 to 6000	6000 to 8000	8000 to 10000	10000 to 12000	12000 to 14000	14000 to 16000	16000 to 18000
10	8000	0.01	0.01	0.03	0.04	0.05	0.09	0.10	0.11	0.14	0.42					
11	10000	-0.04	-0.01	-0.02	-0.01	0.02	0.08	0.08	0.06	0.09	0.20	0.55				
12	12000	-0.01	-0.01	-0.02	-0.01	0.00	0.06	0.06	0.06	0.06	0.14	0.19	0.48			
13	14000	-0.02	-0.07	-0.08	-0.02	-0.01	0.05	0.03	0.07	0.09	0.16	0.11	0.19	0.50		
14	16000	-0.02	-0.02	-0.03	-0.02	-0.01	0.03	0.04	0.03	0.02	0.11	0.17	0.14	0.15	0.41	
15	18000	0.00	0.00	-0.03	-0.02	0.00	0.05	0.05	0.05	0.03	0.08	0.04	0.13	0.05	0.18	0.39

Table B-3. Weighting factors for density.

Table 2-5. Density Weighting Factors (Type 3 Messages)

Line No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	1.00														
2	.43	.57													
3	.22	.31	.47												
4	.15	.21	.32	.32											
5	.11	.17	.25	.22	.25										
6	.08	.11	.17	.17	.15	.32									
7	.06	.08	.14	.13	.12	.22	.25								
8	.05	.06	.11	.11	.10	.19	.17	.21							
9	.04	.06	.09	.09	.08	.17	.15	.14	.18						
10	.03	.04	.07	.07	.07	.13	.12	.11	.11	.25					
11	.01	.03	.05	.05	.06	.12	.11	.09	.09	.16	.23				
12	.02	.03	.05	.05	.05	.11	.10	.09	.08	.14	.12	.16			
13	.02	.02	.04	.05	.05	.11	.09	.09	.08	.14	.10	.09	.12		
14	.02	.03	.05	.05	.05	.10	.09	.08	.07	.13	.11	.08	.06	.08	
15	.02	.04	.05	.05	.05	.10	.09	.08	.07	.12	.09	.08	.05	.05	.06

Table B-4. Weighting factors for wind. These factors are used to weight the wind components (u, v).

Table 2-9. Wind Weighting Factors (Type 3 Message)

Line No.	Zone No.														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	1.00														
2	.20	.80													
3	.09	.19	.72												
4	.06	.12	.26	.56											
5	.04	.08	.15	.20	.53										
6	.03	.05	.08	.09	.12	.63									
7	.02	.03	.07	.07	.08	.20	.53								
8	.02	.02	.06	.06	.06	.14	.19	.45							
9	.02	.02	.05	.05	.05	.12	.13	.20	.36						
10	.01	.02	.02	.04	.03	.07	.08	.09	.09	.55					
11	.00	.00	.01	.04	.03	.08	.08	.09	.09	.20	.38				
12	.00	.01	.01	.02	.04	.07	.07	.07	.08	.17	.16	.30			
13	.00	.01	.01	.01	.03	.07	.07	.07	.07	.15	.14	.13	.24		
14	.00	.01	.01	.01	.02	.07	.07	.07	.07	.13	.13	.13	.10	.18	
15	.00	.01	.01	.01	.02	.07	.07	.07	.07	.12	.12	.11	.10	.08	.14

Table B-5. Atmospheric structure of MET messages from FM 3-09.15 (FM6-15)/MCWP 3-16.5. The second and third columns (labeled COMPUTER for METCM and BALLISTIC for METB3) are relevant to this report.

HEIGHT (meters)	LINE (ZONE) NUMBERS				
	COMPUTER	BALLISTIC	TARGET ACQUISITION	SOUND RANGING	FALLOUT
SURFACE	0	0	0	0	0
50			1		
100	1	1	2	1	
200			3		
300			4		
400	2	2	5	2	
500			6		
600			7	3	
700			8		
800	3	3	9	4	
900			10		
1,000			11		1
1,100			12		
1,200			13		
1,300	4	4	14		
1,400			15		
1,500			16		
1,600			17		
1,700			18		
1,800	5	5	19		
1,900			20		
2,000			21		
2,100			22		
2,200			23		
2,300	6		24		
2,400		6	25		
2,500			26		
2,600			27		2
3,000	7				
3,500	8				
4,000	9	7			
4,500	10				
5,000	11	8			3
6,000	12	9			
7,000	13				
8,000	14	10			4
9,000	15				
10,000	16	11			5
11,000	17				
12,000	18	12			6
13,000	19				
14,000	20	13			7
15,000	21				
16,000	22	14			8
18,000	24				
19,000	25				
20,000	26				10
......					.....
30,000					15

Standard Atmosphere as defined in FM 3-09.15 (FM6-15)/MCWP 3-16.5:

"When computing trajectories, ordnance ballisticians use the International Civil Aviation Organization (ICAO) standard atmosphere. This standard atmosphere is the basis for all data of the ballistic solution as well as a point of departure for ballistic MET corrections. The ICAO atmosphere at sea level is described as follows:

- Dry air.

- No wind.

- Surface temperature of 15 Celsius degrees with a decrease, or lapse rate, of −6.5 Celsius degrees per 1,000 meters up to a height of 11,000 meters and a constant temperature of −56.5 Celsius degrees between 11,000 and 25,000 meters.

- Surface pressure of 1,013.25 millibars, decreasing with height.

- Surface density of 1,225 grams per cubic meter (gm/m^3), decreasing with height."

List of Symbols, Abbreviations, and Acronyms

AFATDS   Advanced Field Artillery Tactical Data System

AGL   above ground level

ARDEC   Armaments Research, Development, and Engineering Center

ARL   U.S. Army Research Laboratory

CMD-P   Computer, Meteorological Data – Profiler

dll   dynamic link library

ICAO   International Civil Aviation Organization

IDE   Integrated Development Environment

MET   meteorological

METB3   ballistic MET message for surface to surface trajectories

METCM   computer MET message

METGM   gridded MET message

NATO   North Atlantic Treaty Organization

NWP   numerical weather prediction

PDA   personal digital assistant

PIBAL   pilot balloon

YPG   Yuma Proving Ground